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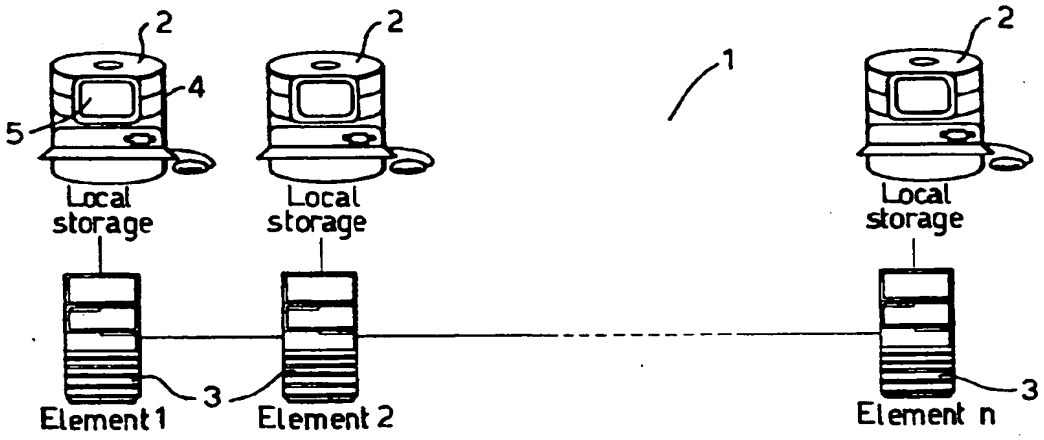

(57) Abstract

The invention provides a method of controlling acceptance of a call by a network node (2 and 3) in a communications network (1) having a required quality of service comprising the steps of determining an infimum of a function of the probability of the node being overloaded if the call is accepted and determining from that infimum the effective bandwidth of the calls to the node if that call should be accepted and determining a corresponding quality of service. The corresponding quality of service is then compared with a quality of service that is required for satisfactory operation of the network. If the quality is maintained or exceeded then the call is accepted for the node.

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METHOD AND APPARATUS FOR CONTROLLING A COMMUNICATIONS NETWORK

This invention relates to a method and apparatus for controlling a communication network, particularly, but not exclusively, an asynchronous transfer mode (ATM) network.

ATM networks are controlled to allow statistical multiplexing of calls which enables more calls to be carried than if Synchronous Transfer Mode (STM) methods are used.

Each node or resource in a communications network will have a certain carrying capacity. The capacity comprises an ability for that node to carry a certain number and type of calls. A call comprises a number of connections each connection being a logical end to end link. In order to prevent a node being overloaded it is necessary to control the acceptance of calls by the node and this is achieved by Connection Acceptance Control (CAC) methods.

The revenue generation from any telecommunication network is closely linked to the number of calls allowed onto the network. Therefore, a CAC algorithm needs to be chosen which will maximise the number of calls admitted to the network, whilst maintaining call Quality of Service (QoS), and considering the network resources available. Of additional importance is the speed with which the CAC algorithm makes call acceptance decisions, as this impacts on the subjective customer perception of the service provided.

The QoS of a network or a node of a network depends on various parameters or sets of parameters. The parameters include the probability of the loss of a particular cell of data as it travels through the network, called the cell loss probability (a cell being a time division of the multiplexing scheme containing the packet of data, which is 48 bytes/octets of information and 5 bytes/octets of control information); cell delay which is a measure of the delay a cell experiences as it passes through the network; and cell delay variation which is a measure of the differences in the

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cell delay times of different cells.

Present CAC methods utilise a procedure called convolution. Convolution based methods are accurate but require considerable computational power and, even then, take a long time causing delays in call set-up on the network which may be unacceptable for certain types of call or services. This problem becomes more and more significant as the mixture of calls becomes more varied. For example, a Broadband Integrated Services Digital Network (BISDN) could carry calls carrying voice data, digital TV data, digital high definition TV data, teleconferencing data, and multimedia data. The data will have different characteristics, for example it could be constant bit rate or variable bit rate and the bandwidth required may also be different, for example, a voice call might require 64 kbps, but a video call might require 140Mbps. Each node in the network will be able to carry either a certain number of identical connections with the same bandwidth requirements, for example, all voice or, as is more likely, a certain number of different types of calls with different bandwidth requirements, for example, both voice and video.

The rate of a cell stream within a call may also be statistically varying. The statistical variations of the cell stream are often modelled by distributions such as Normal, Guassian, on-off or Bernoulli. A moment generating function of a particular distribution is a way of summarising the behaviour of the distribution in terms of its statistical variation.

According to a first aspect of the invention there is provided a method of controlling acceptance of a call for a node in a communication network, the node having a call carrying capacity C and the network having a required quality of service, which method comprising:

determining a function, f(t), of the probability of the node being overloaded if the call is accepted;

determining a value θ which gives an infimum of the function f(t);

determining from the value θ an effective bandwidth if the call is accepted onto the node;

determining from the effective bandwidth and the capacity C a quality of service should the call be accepted; and

comparing the determined quality of service with the required quality of service and if the determined quality of service is not less than the required quality of service accepting the call for the node.

By utilising the effective bandwidth determined from the value θ the quality of service may be determined more quickly than the previous convolution methods. Preferably, the quality of service parameter used is cell loss probability and this is determined from the effective bandwidth utilising value θ. This is compared with the required cell loss probability of the network and if the required cell loss probability is not exceeded the call is accepted for the node.

The capacity of the node, C, may be determined as the network operates or at an initial pre-operation stage and stored in the node or a network management system controlling the node. Similarly, the effective bandwidth may be calculated as the network operates from an "on-line" generated θ value or values or from stored θ value or values. The θ value or values may be stored in look up tables or other data structures and extracted when required. This will be preferable where an even faster control method is required.

The method may be carried out by each node in the network or by an element manager that controls all the nodes in the network.

Preferably, the required quality of service for a call is determined from parameters declared by the call. The declared parameters may be the required mean or peak bit rates, whether the call is constant bit rate or variable bit rate or other parameters. It may also be defined by the customer in a contract for the services.

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According to a second aspect of the invention there is provided apparatus for controlling acceptance of a call for a network node, having a call carrying capacity C, in a communication network, which network having a required quality of service, comprising means for:

determining a value θ which gives an infimum of a function f(t) of the probability of the node being overloaded if the call is accepted;

determining from the value θ an effective bandwidth if the call is accepted onto the node;

determining from the effective bandwidth and the capacity C a quality of service for the node should the call be accepted; and

comparing the determined quality of service with the required quality of service and if the determined quality of service is not less than the required quality of service accepting the call for the node.

Specific embodiments of the invention will now be described by way of example only, with reference to the accompanying drawing in which:

Figure 1 shows a communications network operating in accordance with embodiments of the invention;

Figure 2 is an illustrative diagram of the network shown in Figure 1;

Figure 3 shows in schematic block diagram form a node of the network adopting the role of an element manager;

Figures 4 and 5 show in schematic form data structures of the node shown in Figure 3;

Figure 6 is a chart of the network's operation;

Figure 7 is an explanatory diagram showing the acceptance boundary for a mix of two call classes;

Figure 8 is a diagram of a data structure used in an embodiment of the invention;

Figure 9 shows a further communications network; and

Figure 10 shows in schematic form further data structures.

As shown in Figure 1, a communications network

generally indicated at 1 comprises a plurality of network nodes 2 and associated network elements 3. Each element 3 can be thought of as a switching element which transmits data from node to node in the network. The elements thus form transmission paths between nodes as is more clearly shown in Figure 2.

The way in which calls are routed through the network is well known to those skilled in the art and could be governed by Eurescom P106 VP Handling Functional Model, Dynamic Alternate Routing or Adaptive Alternative Routing. Call set up is achieved by a well known signalling protocol such as ITU specification Q2931.

Each node controls its associated elements 3, that is to say the communications network 1 has localised control as opposed to central control where there is a central element manager. The node 2 comprises a data store 4 and a computer 5. Each element 3 and each computer 5 and data store 4 is of known type and will thus not be described in greater detail.

Each element controls acceptance of calls onto itself. Each element can therefore be considered to have an element manager which has a datastore 4 configured as shown in figure 3. The data store comprises a number of data storage areas 4a to 4g.

Storage area 4a stores information for classifying calls and is called the call class data store. The call class data store comprises a memory structure configured in the form of a look-up table. The look-up table is shown in Figure 4 and it comprises four data fields, $4a_1$, $4a_2$, $4a_3$ and $4a_4$. Data field $4a_1$ contains a service class number. Data field $4a_2$ contains a description of the service as a string of characters. Data field $4a_3$ contains peak rate ranges in Mbps (Mega bits per second) into which calls attempting connection to the network will fall and field $4a_4$ contains information about the bit rate types which can be CBR, constant bit rate, or VBR, variable bit rate.

Taking service class 3.1 for example it can be seen that it is a video conferencing service having a declared

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peak bit rate range of (2, 10] Mbps and the bit rate type is constant bit rate. (This means that the declared peak bit rate X will be $2 < X \leq 10$ Mbps).

Data store 4b is called the entity profile database because it contains a table of service class numbers and appropriate quality of service values, in this case the cell loss probability that is acceptable for the class. Figure 5 shows the table and it can be seen that the service class numbers are contained in the data field $4b_1$, whilst the quality of service values are contained in the data field $4b_2$. Hence, it can be seen that a call of class 2.1 requires a quality of service having a cell loss probability of 1×10^{-7} or better.

The entity profile allows potential calls to be compared and assigned a class. There are n service classes in the network defined by the vector $S = (s_1, \ldots, s_n)$ where each of the elements in S are tuples describing the call classes, that is to say each element of vector S is a combination of entries of the tables shown in figures 4 and 5.

Storage area 4c contains a matrix of information about the calls in progress throughout the network and is hence called a Calls In Progress data store. In greater detail, this stores the number of calls in progress for each network element, and for each call class using a network element for all the elements in the network. The matrix that is stored is called C in P which can be expressed as C in P = $(\bar{n}_1, .., \bar{n}_m)$, where the $\bar{n}_i$ denotes the calls in progress on the element i, and there are m elements in the network. Each of the $\bar{n}_i$ decompose into an array which shows the number of calls of each class which are using the element that is to say $\bar{n}_i = (nc_{i1}, \ldots, nc_{in})$, for n classes and $i \in (1, .., m)$.

The integer matrix C in P is effectively an m x (n + 1) matrix where the elements $\{nc_{ik}\}$ are defined as follows:

$$nc_{ik} = \begin{cases} \text{the number of connections on the element } i \text{ if } k = 0 \\ \text{the number of connections of class } k \text{ on element } i \text{ if } k \text{ is greater than } 0 \end{cases}$$

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Storage area 4d contains a switch routing table which holds information about the adjacent nodes and elements in the network, such as, their call carrying capacity.

Storage area 4e contains a matrix of QoS relations. These are the effective bandwidths of each call type which is using the node at current time (called a_{jk}). It is a real matrix of size m x (n + 2) which stores the current coefficients a_{jk} in each service class for the m elements in the network and the n service classes. The (n + 1)th column stores the real value $C_i\theta_{(i)}/\ln 10$ and the (n + 2)th column stores the target cell loss probability for the element. The target QoS is found by considering the mix of classes on the element, and finding the lowest required cell loss probability for the classes.

QoS Relations Matrix is $\begin{bmatrix} a_{1,1} - a_{1,n} & a_{1,(n+1)} & a_{1,(n+2)} \\ a_{2,1} - a_{2,n} & a_{2,(n+1)} & a_{2,(n+2)} \\ a_{m,1} - a_{m,n} & a_{m,(n+1)} & a_{m,(n+2)} \end{bmatrix}$

Data storage area 4f is configured as a table of data values θ which are to be used to generate effective bandwidth. The values of θ are for a number of mixes of call classes that will use a typical node and element in the network. The values θ are values which provide infimums for the function f(t) that is f (θ) is the infimum. The function f(t) may use the Chernoff bound to calculate the effective bandwidth for each class of call. The effective bandwidths are derived from the moment generating function. The theorem

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states that

$$\ln (P\{Sn \geq C\}) \approx \inf_{t} [n\ln(M(t))-tC]$$

where C is the capacity of the link.

Sn is the superposition of all calls, ie. the load on the link.

n is the number of calls.

M(t) is the moment generating function (which for example, for on-off traffic would be M(t) = mexp (θp)+1-m. where m is the mean and p the peak)

The expression states that the natural logarithm of the probability of the link load (Sn) exceeding the link capacity C is given by the infimum (or the greatest lower bound) (over θ) of the expression in square brackets. θ is a value of t which satisfies this theorem.

These are pre-calculated when the network is configured and stored in the tabular form so that appropriate θ values may be used to generate effective bandwidths without the θ values having to be generated each time.

The last data store 4g is a short term memory which stores a matrix of size m x (n + 2) containing the QoS relations for the route of a connection. The matrix is created whenever a new call arrives in a manner that will be described later.

The computer 5 is programmed to carry out the method according to the invention. It provides an element managing function and thus can be considered as an element manager

labelled 5a in the diagram. The element manager 5a has access to the data storage areas 4a to 4g and processes call information to control call acceptance by elements and nodes on the network 1 (including its associated element). The data storage areas 4a to 4f and its associated switching element are connected to the element manager 5a by databuses of a well known type.

The way in which a call is accepted or rejected for an element by each node in the network is illustrated by the flowchart shown in figure 6.

The first step is to initialise the data storage areas, block 6. This results in the previously described storage areas 4a to 4g being configured and initial values being entered including the calculation of θ values and their entry into the table stored in data storage area 4f.

The θ values are calculated off-line and loaded by the element manager 5a at initialisation. For example, if a call having a peak bit rate of 2Mbits/sec and a mean of 0.2 Mbits/sec is to be multiplexed on a 140 Mbits/sec link then from Chernoff's theorem (also known as the Chernoff bound or the Large Deviation bound) it follows that:

$$\ln (P\{Sn \geq C\}) \approx \inf_t [n \ln(M(t)) - tC] \qquad (2)$$

Where C is the capacity of the link which for simplicity is expressed in terms of peak call bit rates that

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is to say 140/2 = 70.

Sn is the superposition of all calls that is to say the load on the link.

n is the number of calls.

M(t) is the moment generating function which for on-off traffic becomes $M(t)=m\exp(tp)+1-m$ where p is the peak bit rate which is now 1 because the capacity has been normalised by the peak call rate and m is the mean call rate which because the peak has been normalised to 1 should then be $0.2/2=0.1$

therefore, $M(t)=0.1\exp(t)+1-0.1$.

Equation 2 is an expression that the natural logarithm of the probability of the load of a link (Sn) exceeding its capacity (C) is given by the infimum over θ (or the greatest lowest bound of the expression in the square brackets).

Theta is calculated off-line by differentiating the expression 2 with respect to t. Therefore the equation is

$$\frac{d}{dt}\ln(P\{Sn \geq C\}) = \frac{nmp\exp(tp)}{m\exp(tp)+1-m} - C \qquad (3)$$

For the minimum this derivative is set to zero and solved for t. The value of t is theta.

$$\frac{nmp\exp(tp)}{m\exp(tp)+1-m} - C = 0 \qquad (4)$$

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With the above conditions this simplifies to

$$\frac{0.1n \exp(t)}{0.1 \exp(t) + 0.9} - 70 = 0 \qquad (5)$$

Thus, an appropriate value of $t = \theta$ for the above conditions is generated and stored for use by the element manager 5a.

In a similar way θ values for heterogenous mixes of call types can be derived for various numbers and mixes of calls to give a discrete range of values from which an appropriate θ value may be chosen for the load on the network whilst it is in operation.

The nodes in the network then await a call as represented by the idle block 7.

A call then arrives at a node as represented by call arrival block 8 and its declared characteristics compared by the element manager 5a with the characteristics stored in the call class storage area 4a and the appropriate call class determined. In this way the call is assigned to a class, block 9. For example, the call may have a declared peak bit rate of (0, 0.064]Mbps and be of a variable bit rate VBR type. (The notation (x,y] meaning a value greater than x but less than or equal to y, that is to say, in this case a value greater than 0 but less than or equal to 0.064). A service class of 1.2 equates to this declared peak and bit rate type.

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This value is returned to the element manager 5a which inputs this service class into the entity profile storage area and from Figure 5 it can be seen that a quality of service value QoS of 1×10^{-9} is returned. Thus the chosen element must offer a cell loss probability of not more than 1×10^{-9}.

The next step is to choose a suitable element to carry the call, block 10. The switch routing table 4d is consulted to choose a suitable element. The element is chosen for its ability to carry call of a particular class in the required logical direction through the network.

The element manager 5a then determines if a call of this class is already using the chosen element, block 11, by referring to the calls in progress storage area 4c. For example, consider the situation where a call is of class k and the chosen element is e_1. If there are calls of this class in progress on this element, the value of nc_{ik} of the calls in progress matrix stored in storage 4c would be greater than zero. If this is so, the network manager 5a then inspects the quality of service relation, block 12, (to be described later) otherwise, the information is used to recalculate the quality of service relation, block 13, (as described later).

In the case of nc_{ik} being greater than zero, the element manager 5a inspects the quality of service relation stored in the storage area 4e and determines the effect of adding a call of type k on the element e_i on the quality of

service. This is represented by block 14. If the quality of service is still acceptable, that is to say, maintained, then the call is accepted for the element.

For the new call to be accepted

$$\Rightarrow \text{Target QoS for element } i \geq a_{i1}nc_{i1} + a_{i2}nc_{i2} + \ldots + a_{ik}(nc_{ik} + 1) + \ldots + a_{in}nc_{in} - \frac{C_i\theta}{\ln 10} \quad (1)$$

where C_i = the capacity of the resource i,

θ_i = the required theta value used to calculate the effective bandwidth for this mix of calls on the element.

a_{ij} = the effective bandwidth calculated from the Chernoff bound (utilising the θ value).

This reduces to a linear relation. For two call types, the QoS relation for element 1 for the new call to be accepted might be of the form $0.1nc_{11} + 0.01nc_{12} - 0.5 \leq 10^{-2}$, for example.

To perform this calculation the element manager 5a obtains a θ with reference to the table of θ values in storage area 4f which were created on initialisation, block 6. This is the appropriate value according to the traffic mix of classes being selected. Each θ provides a tangent to an acceptance boundary for the particular mix of calls. It can be thought of as the "temperature" of the multiplexing

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potential. A low value for theta implies that the potential for multiplexing gain given the call mix is high. Conversely, a high value of theta implies that the potential for multiplexing gain with this mix of calls is low.

Consider for example the mix of constant bit rate voice data and variable bit rate video data shown as a graph in figure 7. The acceptance boundary is shown in broken outline 10 and the θ values stored in the table of θ values are θ_1, θ_2 and θ_3.

For X on the graph θ_3 is the θ value to be used to calculate the effective bandwidths.

Similarly for point y, θ_2 is the appropriate value to use and for point Z θ_1 is the appropriate value.

If the QoS falls below that required for the element then the call is rejected for the element, block 15. Another element has to be found, block 16, or the call is not accepted on to the network 1 which returns to idle, block 7.

If the value of nc_{ik} is zero the element manager 5a recalculates the quality of service relation for the element i, block 13. It does this by extracting from the database table of θ values stored in storage area 4f, a θ value appropriate to the new traffic mix. Before determining whether or not a call is accepted it assumes that it will be accepted in order to select the appropriate θ value. If the connection belongs to a class which is new to the element, the QoS relation stored in the nodes short term memory data

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store overwrites the relation stored in the QoS data store.

That value of θ is then inserted into relationship 1. If a new QoS for the element i is less than or equal to the target cell loss probability then the new call is accepted, otherwise it is rejected. If the call is accepted the new QoS relation is written in the short term memory store 4e as represented by block 17.

The next element in the route through the network 1 is then connected and the process repeated until the last element for connection is reached, block 18. The call is then accepted throughout the network, block 19.

When all the elements in an end-to-end connection have accepted the connection, the calls in progress data storage area is updated by adding one to the class of connection that has been accepted. When the call finishes that is to say clears down, block 20, the calls in progress data storage area is again updated, block 21.

To further illustrate the way in which the embodiment of the invention operates there shall be described a number of network examples each one comprising network nodes and elements as earlier described and configured and operated in the same manner.

In a first example of a five node, six element network shown in figure 9, the available capacity of all the links or elements is 140Mbps. Ideally, calls entering the network declare their mean bit rate as well as their peak bit rate.

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If only the peak rate is given, then the call is assumed to CBR where the mean is the peak.

For call traffic that is on/off or burst type the Moment Generating Function is

$M(t) = m_1 \exp(\theta p_1) + 1 - M_1$

where

p_1 = the peak bit rate requirement for a call of class 1.

m_1 = the mean bit rate requirement for a call of class 1 (expressed as peak/mean).

θ = the infimum θ or "temperature".

There are two service classes in the network defined by the vector $S = (S_1, S_2)$ where each of the elements in S is defined by the following service class definitions.

Service Class S_1, telephony service having a declared peak range of (0, 0.064]Mbps being constant bit rate (CBR) requiring a quality of service (Qos) of $1x10^{-2}$; and Service Class S_2, video telephony service (HQ) having a declared peak range of (0.064, 2] and being of variable bit rate (VBR) requiring a quality of service of 1×10^{-7}. This data is held as earlier described in the call class storage area 4a.

With calls of different classes sharing the link the lower cell loss probability of $1x10^{-7}$ must be maintained.

In this example, there are $\sum_{i=1}^{2} {}^2C_i = 3$ values for θ in the database. This formula is a general dimensioning algorithm for the θ database, that is, the maximum number of θ values

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to be stored in the database for n call classes is $\sum_{i=1}^{n} {}^{n}C_{i}$. (This number can be reduced by only storing non-unity values for θ). The set of θ values is defined by $A=\{\theta_{(1)}, \theta_{(1,2)}, \theta_{(2)}\}$. For this example, the set is thus $A=\{1, 0.8333, 0.4143\}$. The first entry is a value which is chosen to be one arbitrarily because in this case there are only calls of service class S_1 on the network which are constant bit rate CBR. Peak rate allocation is then used and statistical multiplexing is not possible. All the values for θ are stored in the storage area 4f.

Suppose at a particular point in time the network carries a load such that elements e_2 and e_5 carry six hundred 64kbps CBR voice calls and twenty three 2Mbps VBR high quality video calls. There is no other traffic on any of the other elements e_1, e_4, e_3 or e_6.

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The calls in progress matrix C in P is as earlier described, stored in storage area 4c. The matrix is:

$$C \text{ in } P = \begin{bmatrix} \text{No of calls of class } S_1 \text{ and } S_2 \text{ on } e_1 & \text{No of calls of class } S_1 \text{ on } e_1 & \text{No of calls of class } S_2 \text{ on } e_1 \\ \text{No of calls of class } S_1 \text{ and } S_2 \text{ on } e_2 & \text{No of calls of class } S_1 \text{ on } e_2 & \text{No of calls of class } S_2 \text{ on } e_2 \\ \text{No of calls of class } S_1 \text{ and } S_2 \text{ on } e_3 & \text{No of calls of class } S_1 \text{ on } e_3 & \text{No of calls of class } S_2 \text{ on } e_3 \\ \text{No of calls of class } S_1 \text{ and } S_2 \text{ on } e_4 & \text{No of calls of class } S_1 \text{ on } e_4 & \text{No of calls of class } S_2 \text{ on } e_4 \\ \text{No of calls of class } S_1 \text{ and } S_2 \text{ on } e_5 & \text{No of calls of class } S_1 \text{ on } e_5 & \text{No of calls of class } S_2 \text{ on } e_5 \\ \text{No of calls of class } S_1 \text{ and } S_2 \text{ on } e_6 & \text{No of calls of class } S_1 \text{ on } e_6 & \text{No of calls of class } S_2 \text{ on } e_6 \end{bmatrix}$$

for the above conditions this will be

S_1 is 600 x 64Kbps CBR

S_2 is 23 x 2 Mpbs VBR.

$$C \text{ in } P = \begin{bmatrix} 0 & 0 & 0 \\ 623 & 600 & 23 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 623 & 600 & 23 \\ 0 & 0 & 0 \end{bmatrix}$$

The QoS relations are calculated using the peak

and mean bit rates of the two service classes and $\theta_{(1,2)}$ selected from the data storage area since both call classes are using the elements 2 and 5.

$$QoS_2 \text{ and } QoS_5 <= 0.0232n_{21} + 0.1552n_{22} - 50.67.$$

The resulting matrix is

$$\text{QoS Relations Matrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0.0232 & 0.1552 & 50.667 & -7 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0.0232 & 0.1552 & 50.667 & -7 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

Suppose a new call of video call type requiring a peak bit rate of 2Mbps and a mean bit rate of 200kbps requires connection between nodes 1 and 5 of the network shown in figure 10. If the first element chosen by the element manager 5a of node 1 is e_2, since this element already carries this class of call, the QoS_2 is checked first, block 12,

$QoS_2 \leq 0.0232 \times 600 + 0.1552 \times (23 + 1) - 50.667$

since there are six hundred sixty four kbps CBR Voice calls already carried by the element and twenty three existing and one additional two Mbps video calls. Therefore

$QoS_2 \leq -33$ (= cell loss probability of 10^{-33}).

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The QoS is thus maintained, block 14, since 1×10^{-33} cell loss probability is less than the required quality of service which is 1×10^{-7}. The next element chosen is e_5, block 10 and the earlier described steps repeated. An end to end connection exists since e_5 is the last element for connection, block 18, and the call is accepted, block 19.

Suppose the next call that requires routing through the network is carried on elements e_1 and e_4. The new call is of a new class, where there are 1000 x 64kbps calls already on the route e_1, e_4. With the same conditions as before, that is to say, no calls have been cleared down, block 20, load is therefore:

600 x 64kbps CBR voice calls on elements e_2 and e_5

24 x 2 Mbps VBR High Quality Video calls on e_2 and e_5 and

1000 x 64 Kbps voice calls on elements e_1 and e_4.

For this case the Calls in Progress matrix becomes

$$C \text{ in } P = \begin{bmatrix} 0 & 0 & 0 \\ 624 & 600 & 24 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 624 & 600 & 24 \\ 0 & 0 & 0 \end{bmatrix}$$

and the resulting Qos relations matrix is

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$$\text{QoS Relations Matrix} = \begin{bmatrix} 0.0278 & 0 & 60.801 & -2 \\ 0.0232 & 0.1552 & 50.667 & -7 \\ 0 & 0 & 0 & 0 \\ 0.0278 & 0 & 60.801 & -2 \\ 0.0232 & 0.1552 & 50.667 & -7 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

In this instance both the values of $\theta_{(1)}$ and $\theta_{(1,2)}$ are being used. Since $\theta_{(1)}$ refers to CBR rate calls only, which require peak allocation, the QoS relation is just a constraint on the maximum number of connections which can be accepted onto the link that is to say capacity/Peak bit rate.

Suppose the new call is again a video call of type S_2. If the first element chosen by node 1 is e_1, then since this type of call is of a type not already using element e_1 the relation to QoS_1 is recalculated (blocks 8, 9, 10, 11 and 13).

$QoS_1 \leq 0.0232 \times 1000 + 0.1552 \times 1 - 50.667$

$QoS_1 \leq -27$. That is to say the cell loss probability is less than or equal to 1×10^{-27} which is better than the required quality of service and the call accepted on element e_1. The next element chosen is e_4 and since this has the same traffic load, the same conditions prevail and the call is accepted for element e_4 and the relation is for element e_4 is updated in the short term memory store 4g. An end to end route exists, so the call is accepted for the network (block 19). The calls in progress matrix is updated (block 21) and the QoS relation matrix updated from the short term memory stores 4g.

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Suppose the load on the network has increased to

600 x 64 Kbps CBR voice calls on elements e_2 and e_5

24 x 2 Mbps VBR Video calls on elements e_2 and e_5

1000 x 64 Kbps voice calls on elements e_1 and e_4

1 x 2 Mbps VBR Video calls on elements e_1 and e_4

1000 x 64 Kbps voice calls on elements e_3 and e_6

132 x 2 Mbps VBR High Quality Video calls on elements e_3 and e_5.

Under this load the Calls in Progress matrix is

$$C \text{ in } P = \begin{bmatrix} 1001 & 1000 & 1 \\ 624 & 600 & 24 \\ 1132 & 1000 & 132 \\ 1001 & 1000 & 1 \\ 624 & 600 & 24 \\ 1132 & 1000 & 132 \end{bmatrix}$$

The QoS relation matrix is then

$$\text{QoS Relations Matrix} = \begin{bmatrix} 0.0232 & 0.1552 & 50.667 & -7 \\ 0.0232 & 0.1552 & 50.667 & -7 \\ 0.0232 & 0.1552 & 50.667 & -7 \\ 0.0232 & 0.1552 & 50.667 & -7 \\ 0.0232 & 0.1552 & 50.667 & -7 \\ 0.0232 & 0.1552 & 50.667 & -7 \end{bmatrix}$$

It will be noted that since all the elements e_1 to e_6 carry calls of the same classes that the QoS relations (the effective bandwidths) are the same.

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With this load, suppose a video call of class S_2 needs to pass through the network from node 1 to node 6. The element manager 5a at node 1 considers routing it via element e_3.

The new call is of a class already using element e_3, so the QoS relation for element e_3, QoS_3, is checked (block 11).

$QoS_3 \leq 0.0232 \times 1000 + 0.1552 \times (132 + 1) - 50.667$

$QoS_3 \leq -6.9$.

Since the video call requires a guaranteed cell loss probability of 1×10^{-7} the call is rejected for element e_3 (block 15). An alternative element is then chosen (block 16 and block 10) and the process repeated.

In an alternative embodiment of the invention it may be possible to dispense with the tables of θ values and replace it with a data store containing the information to calculate the θ values in an on-line manner.

The method may be improved by the use of a greater number of call classes than used in the above-described embodiment. It may also be possible to define and add a new class to the data store if an unidentified call appears on the network. Alternatively, the database may be updated manually.

By increasing the number of service classes it will mean that each class of traffic is defined more accurately, so that traffic characteristics will be better catered for. This will result in a greater statistical gain but of course

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the data storage requirements will increase.

When choosing the value of θ from a table of θ values, or various θ values derived from more than one moment generating function, it may be possible to select the most appropriate θ value with reference to the time of day. It will be known from an historical database that the traffic will have a certain mix of classes at a particular time of day. As the network is utilised an historical database may be built up which monitors the θ values selected and the efficiency of the resulting multiplexing method and the θ values periodically updated to take account of this performance data in order to optimise the multiplexing gain. This could be done manually but it is envisaged that the network could be configured to do this automatically on a periodical basis. Instead of using a number of θ values, in some embodiments a single value may be used.

The θ table 4f could be provided as a set of θ tables as shown in figure 10. Table $4f_1$ could be used when the time of day is in range t_1, for example 8am to 12am. Table $4f_2$ could be used when the time of day is in the range t_2, for example 12am to 6pm. Table $4f_3$ could be used when the time of day is within the range t_3, for example 6pm to 8am.

To select the appropriate table, the element manager 5a includes a clock. The time of day is determined by the element manager 5a referring to the clock and then according

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to the time of day selecting an appropriate one of the tables $4f_1$, $4f_2$ or $4f_3$.

In a preferred embodiment of the invention the θ values are selected on the basis of thresholds of calls. This requires the number of calls in progress on the link for each service class to be monitored. The thresholds would be stored in a threshold table as shown in figure 8. When the threshold is reached the next value of θ is chosen.

Consider the various possible mixture of call types as shown in figure 7. If the element manager 5a determines that the number of calls of Video VBR type is between 270 to 345 calls, then a θ value θ_3 could be selected (see figure 8). Similarly if the number of 64kbps CBR calls is in the range 1890-2156 θ_1 would be used. Otherwise, θ_2 would be used.

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CLAIMS

1. A method of controlling acceptance of a call for a node in a communication network, the node having a call carrying capacity C and the network having a required quality of service comprising:

determining a function, f(t), of the probability of the node being overloaded if the call is accepted;

determining a value θ which gives an infimum of the function f(t);

determining from the value θ an effective bandwidth if the call is accepted onto the node;

determining from the effective bandwidth and the capacity C a quality of service should the call be accepted; and

comparing the determined quality of service with the required quality of service and if the determined quality of service is not less than the required quality of service accepting the call for the node.

2. A method as claimed in claim 1 wherein the value θ is determined using the Chernoff theorem.

3. A method as claimed in claim 1 wherein the function f(t) is $n[\ln(M(t))-tC]$ where M(t) is the moment generating function and n is the number of calls on the node if the call

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is accepted for the node.

4. A method as claimed in claim 1, claim 2 or claim 3 wherein the quality of service parameter is the cell loss probability.

5. A method as claimed in any preceding claims wherein a plurality of θ values are calculated for different anticipated classes of call types carried by the network each class corresponding to a mixture of call types.

6. A method as claimed in any preceding claims where the θ value or values is/are stored in a memory structure table.

7. A method as claimed in claim 6 wherein the θ values are stored in a memory structure with associated classes.

8. A method as claimed in claim 7 wherein incoming calls to the network or nodes of a network are classified into a class and the θ value appropriate for that class obtained by reference to the memory structure storing the θ values and associated classes.

9. A method as claimed in any one of the preceding claims wherein a θ value is chosen on the basis of numbers of a particular call type being carried by the network and or

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node.

10. A method as claimed in claim 9 wherein the number of calls of a particular call type that would be carried by the node if the call is accepted is determined and compared with at least one threshold value of number of calls in order to select an appropriate θ value.

11. A method as claimed in any one of the preceding claims wherein there is provided a memory structure of threshold values of numbers of calls and corresponding appropriate θ values.

12. A method as claimed in any one of the preceding claims wherein at least one θ value is selected with reference to time.

13. A method as claimed in claim 11 wherein reference is made to the time of day to select at least one θ value.

14. A method as claimed in any one of the preceding claims wherein performance of the communications network is monitored and the at least one θ value or some of the θ values are modified to enhance the performance.

15. Apparatus for controlling acceptance of a call for a node in a communication network, the node having a call

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carrying capacity C and the network having a required quality of service, comprising means for:

determining a value θ which gives an infimum of a function f(t) of the probability of the node being overloaded if the call is accepted;

determining from the value θ an effective bandwidth if the call is accepted onto the node;

determining from the effective bandwidth and the capacity C a quality of service for the node should the call be accepted; and

comparing the determined quality of service with the required quality of service and if the determined quality of service is not less than the required quality of service accepting the call for the node.

16. Apparatus as claimed in claim 15 wherein means are provided to determine the value θ using the Chernoff theorem.

17. Apparatus as claimed in claim 15 or claim 16 wherein means are provided to determine the function f(t) of the probability of the node being overloaded if the call is accepted.

18. Apparatus as claimed in claim 15, claim 16 or claim 17 wherein the function f(t) is n[ln(M(t)-tC] where M(t) is the movement generating function and n is the number of calls on

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the node if the call is accepted for the node.

19. Apparatus as claimed in any one of the preceding claims wherein the means for determining a quality of service parameter determines a cell loss probability.

20. Apparatus as claimed in any one of the preceding claims further comprising memory to store the θ value for subsequent use.

21. Apparatus as claimed in claim 16 wherein the means for determining θ values determines a θ value for different anticipated classes of call types to be carried by the network, each class corresponding to a mixture of call types.

22. Apparatus as claimed in claim 21 further comprising memory means to store the θ values as a table of θ values and corresponding classes of calls.

23. Apparatus as claimed in claim 22 including means to classify incoming calls to the network and for obtaining a θ value appropriate to that class from the memory means storing the θ values and corresponding classes of calls.

24. Apparatus as claimed in any one of the preceding claims wherein the θ value or values used to determine the quality

of service is/are obtained on the basis of numbers of calls of a particular call type.

25. Apparatus as claimed in any one of the preceding claims including means for determining a time of day and to select a θ value or values appropriate to the time of day.

26. Apparatus as claimed in any preceding claim including means to monitor the performance of the communications network and to modify a θ value or values to be used to determine a quality of service from an initial value to modified value in order to improve the performance of the communications network.

27. Apparatus as claimed in claim 26 wherein memory is provided to store the modified value or values.

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Fig.1.

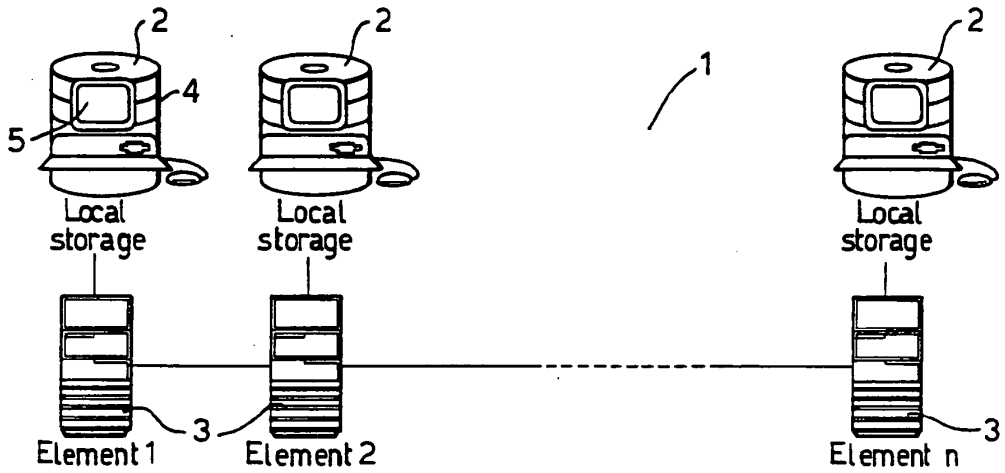

Fig.2.

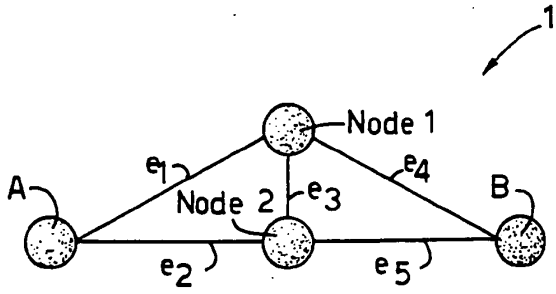

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Fig.3.

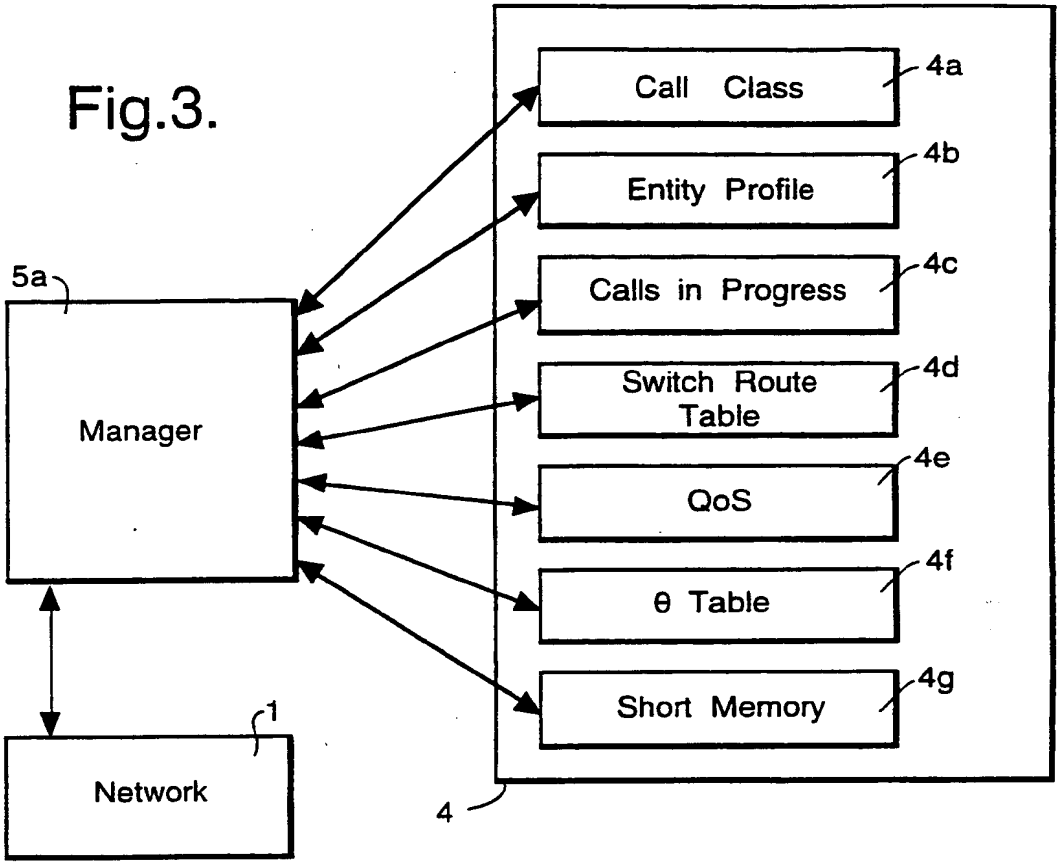

Fig.5.

Service Class (4b1)	QoS (4b2)
1.1	10^{-2}
1.2	10^{-9}
2.1	10^{-7}
2.2	10^{-7}
3.1	10^{-7}
3.2	10^{-7}
4.1	10^{-7}
4.2	10^{-9}

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Fig.4.

4a1 Service Class	4a2 Service	4a3 Declared Peak Mbps	4a4 Bit Rate Type
1.1	Telephony,Fax data Retrieval	(0,0.064]	CBR
1.2	Interactive Services	(0,0.064]	VBR
2.1	Video Conferencing	(0.064,2]	CBR
2.2	Video Telephony (HQ), Interactive Data	(0.064,2]	VBR
3.1	Video Conferencing	(2,10]	CBR
3.2	Video Interactive Data	(2,10]	VBR
4.1	Video Codecs	(10,140]	CBR
4.2	Lan interconnection	(10,140]	VBR

Fig.10.

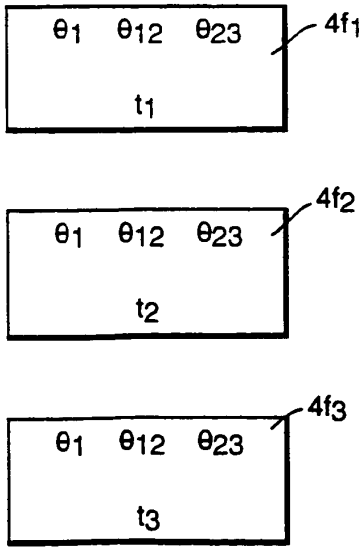

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Fig.6.

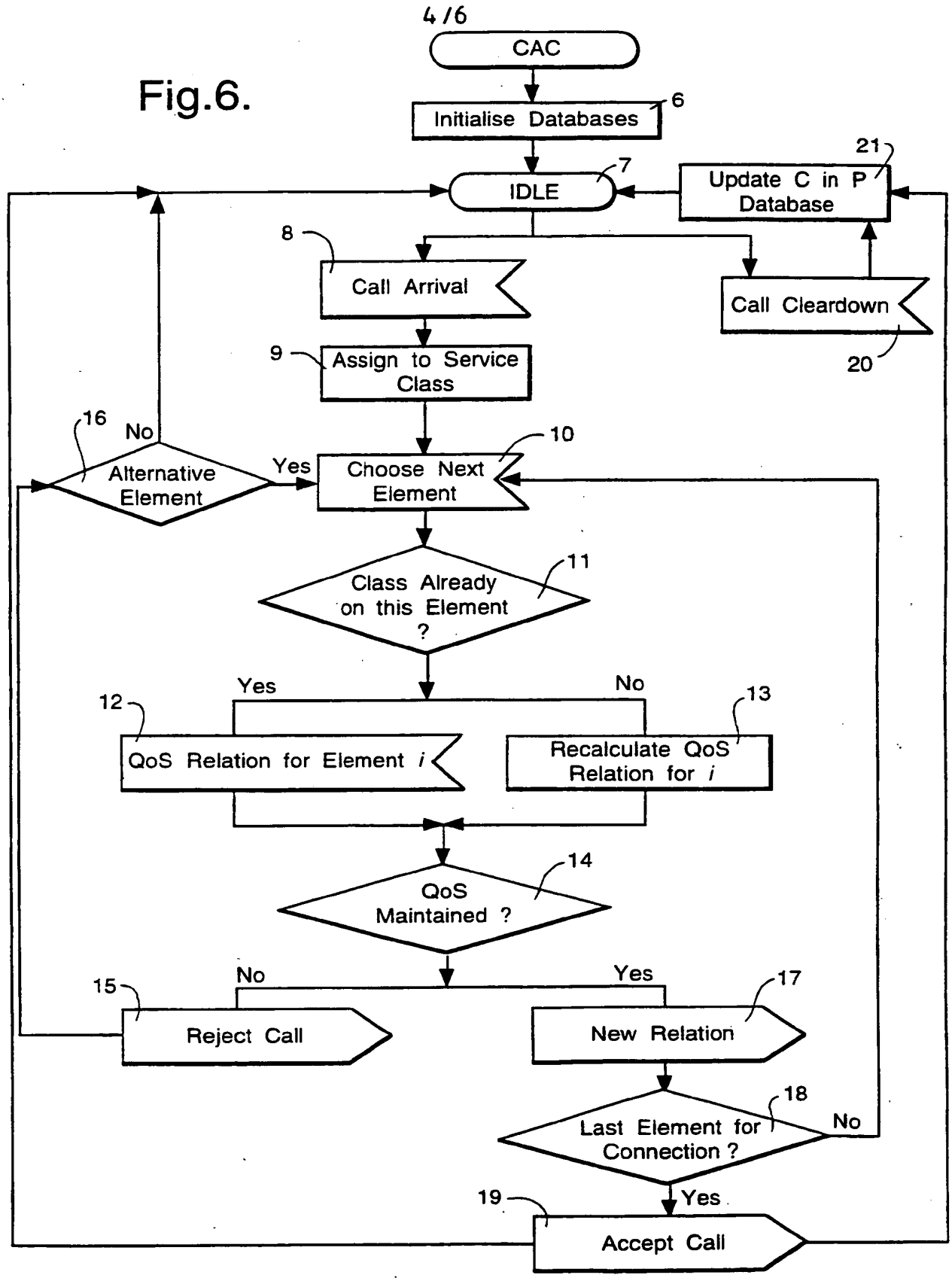

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Fig.7.

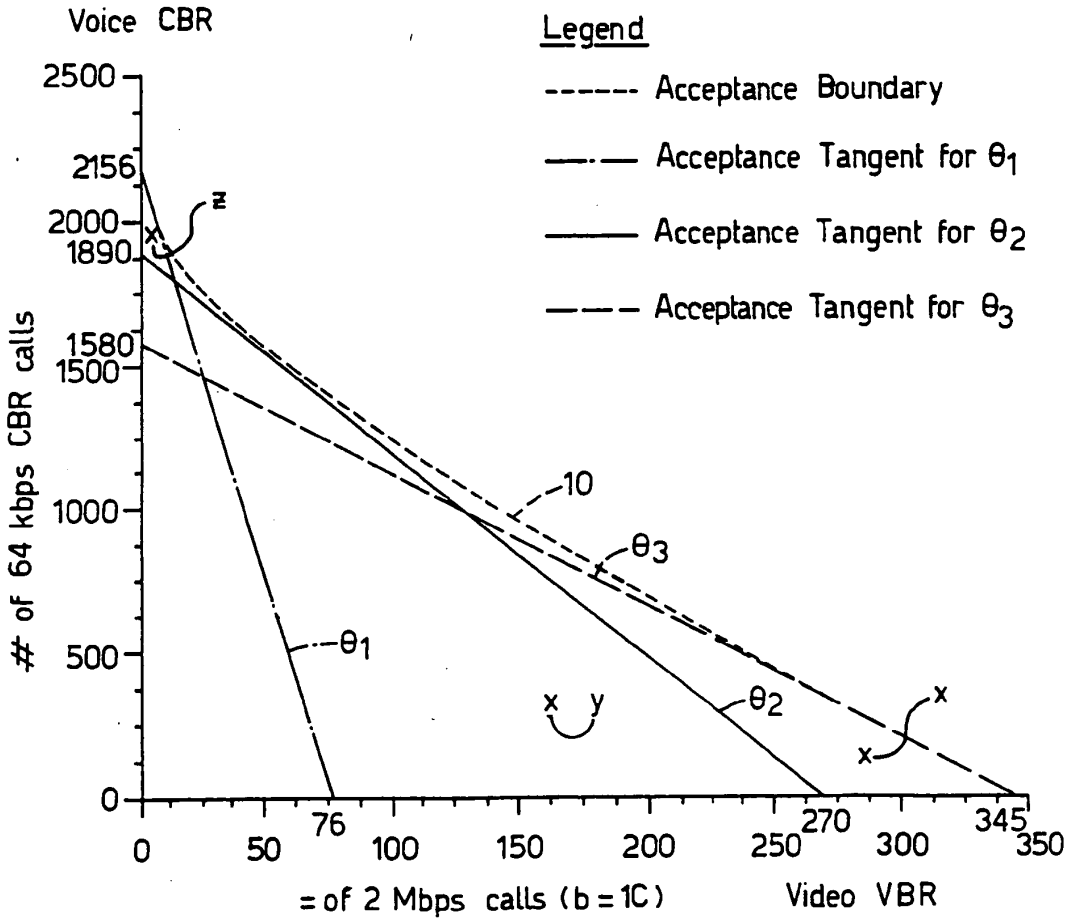

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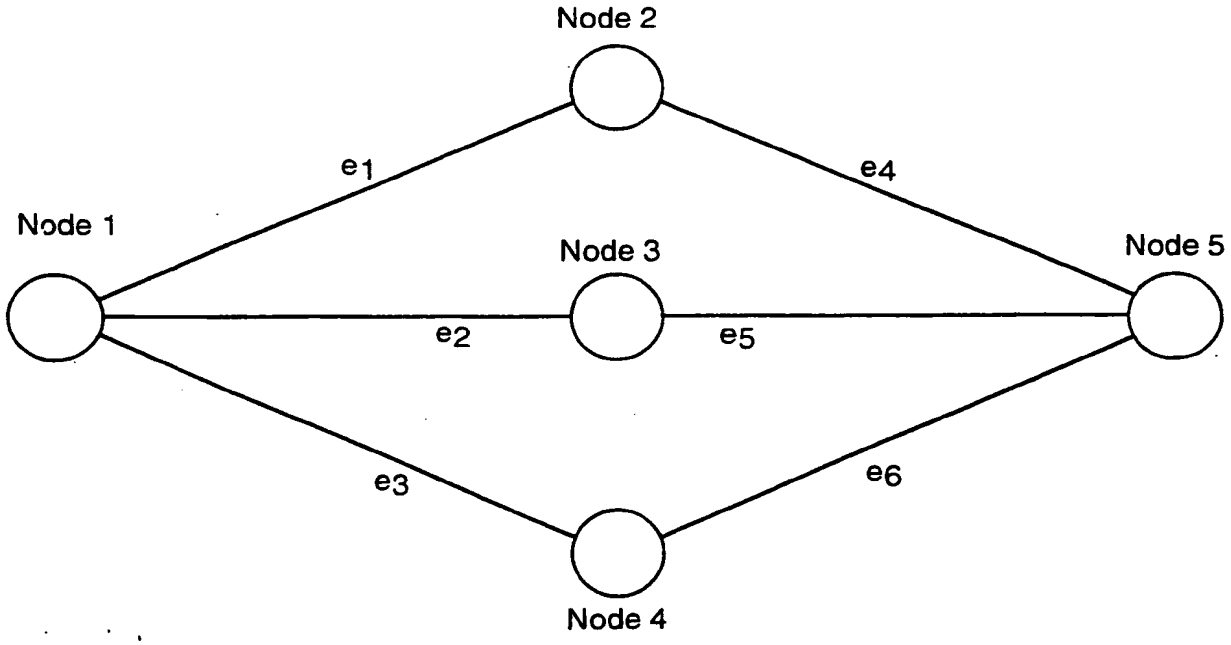
Fig.8.

Region	Threshold Regions for 64 kbps Calls	Threshold Regions for 2 Mbps Calls	Value for θ
θ_1	[1890,2156]	[0,345]	12.23
θ_2	[0,1890]	[0,270]	0.8333
θ_3	[0,1890]	[271,345]	0.4143

Fig.9.



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INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/GB 94/02648

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04L12/56

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	INTERNATIONAL JOURNAL OF DIGITAL AND ANALOG COMMUNICATION SYSTEMS., vol.3, no.2, June 1990, UK pages 127 - 135 J.Y. HUI 'A congestion measure for call admision and traffic engineering for multi-layer multi-rate traffic.' see page 129, right column, line 23 - page 130, right column, line 16 ---	1-27
A	EP,A,0 433 699 (SIEMENS AKTIENGESELLSCHAFT) 26 June 1991 see abstract -----	1,15

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 April 1995	28. 04. 95

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Perez Perez, J

Form PCT/ISA/210 (second sheet) (July 1992)

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter nal Application No
PCT/GB 94/02648

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A-0433699	26-06-91	NONE	

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Fig.1.

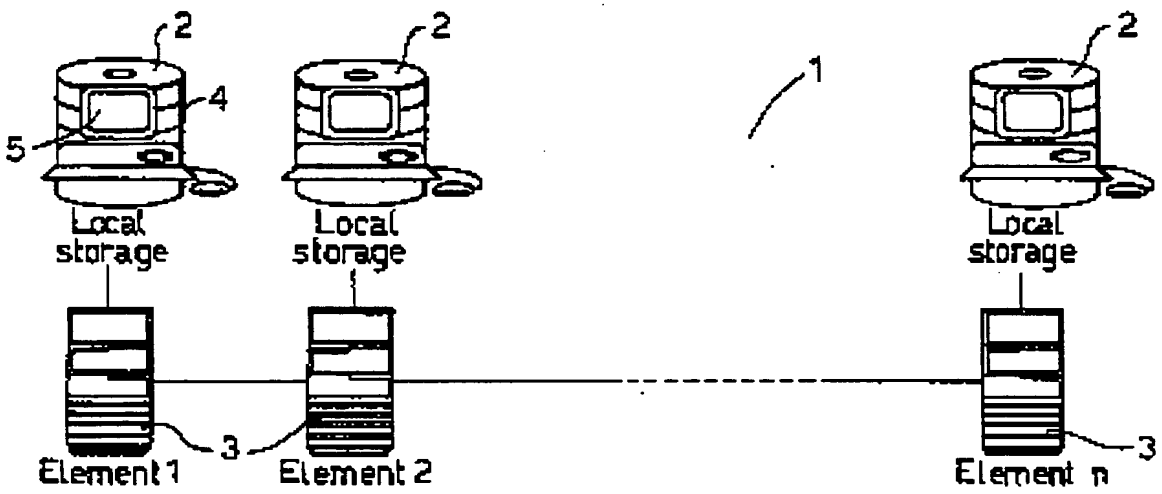

Fig.2.

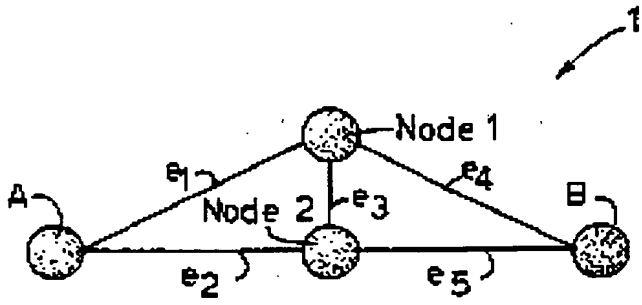

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Fig.3.

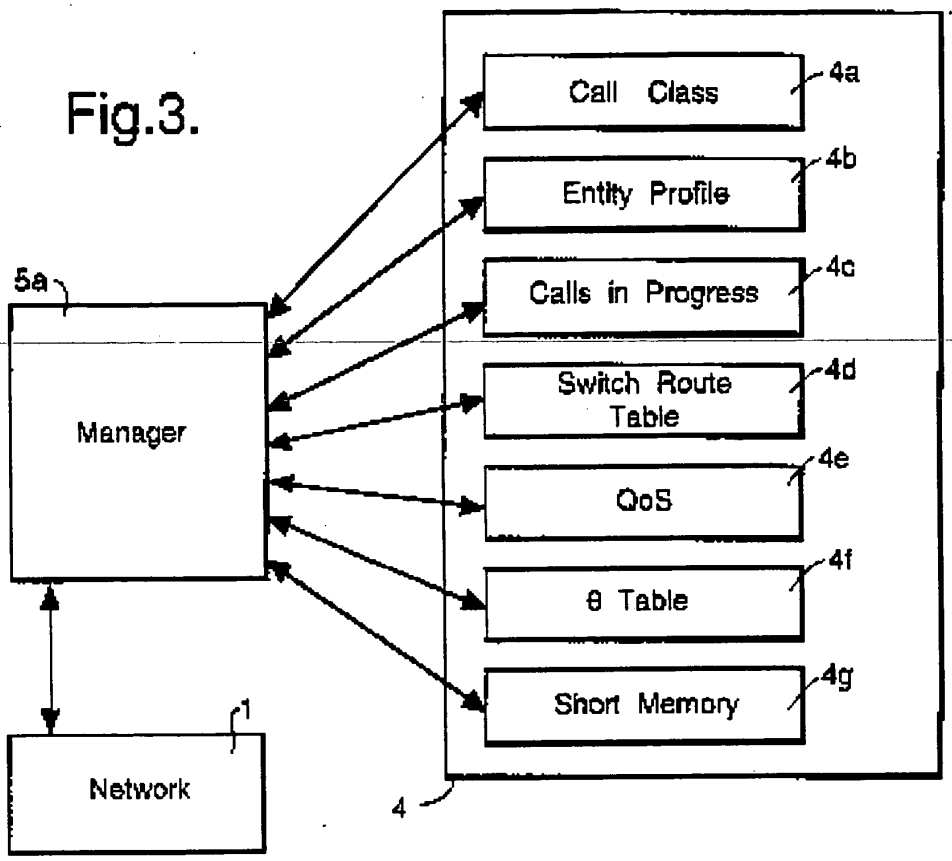

Fig.5.

Service Class (4b1)	QoS (4b2)
1.1	10^{-2}
1.2	10^{-9}
2.1	10^{-7}
2.2	10^{-7}
3.1	10^{-7}
3.2	10^{-7}
4.1	10^{-7}
4.2	10^{-9}

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Fig.4.

4a1 Service Class	4a2 Service	4a3 Declared Peak Mbps	4a4 Bit Rate Type
1.1	Telephony,Fax data Retrieval	(0,0.064]	CBR
1.2	Interactive Services	(0,0.064]	VBR
2.1	Video Conferencing	(0.064,2]	CBR
2.2	Video Telephony (HQ), Interactive Data	(0.064,2]	VBR
3.1	Video Conferencing	(2,10]	CBR
3.2	Video Interactive Data	(2,10]	VBR
4.1	Video Codecs	(10,140]	CBR
4.2	Lan interconnection	(10,140]	VBR

Fig.10.

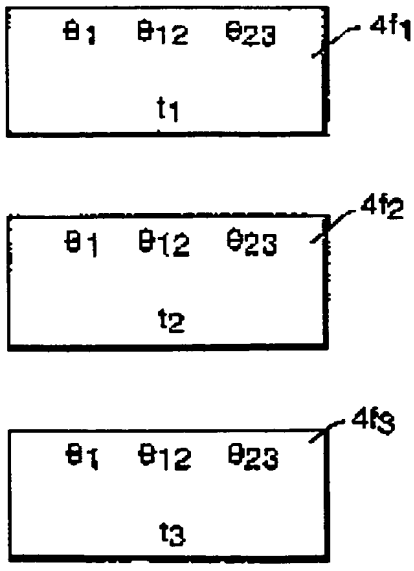

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Fig.6.

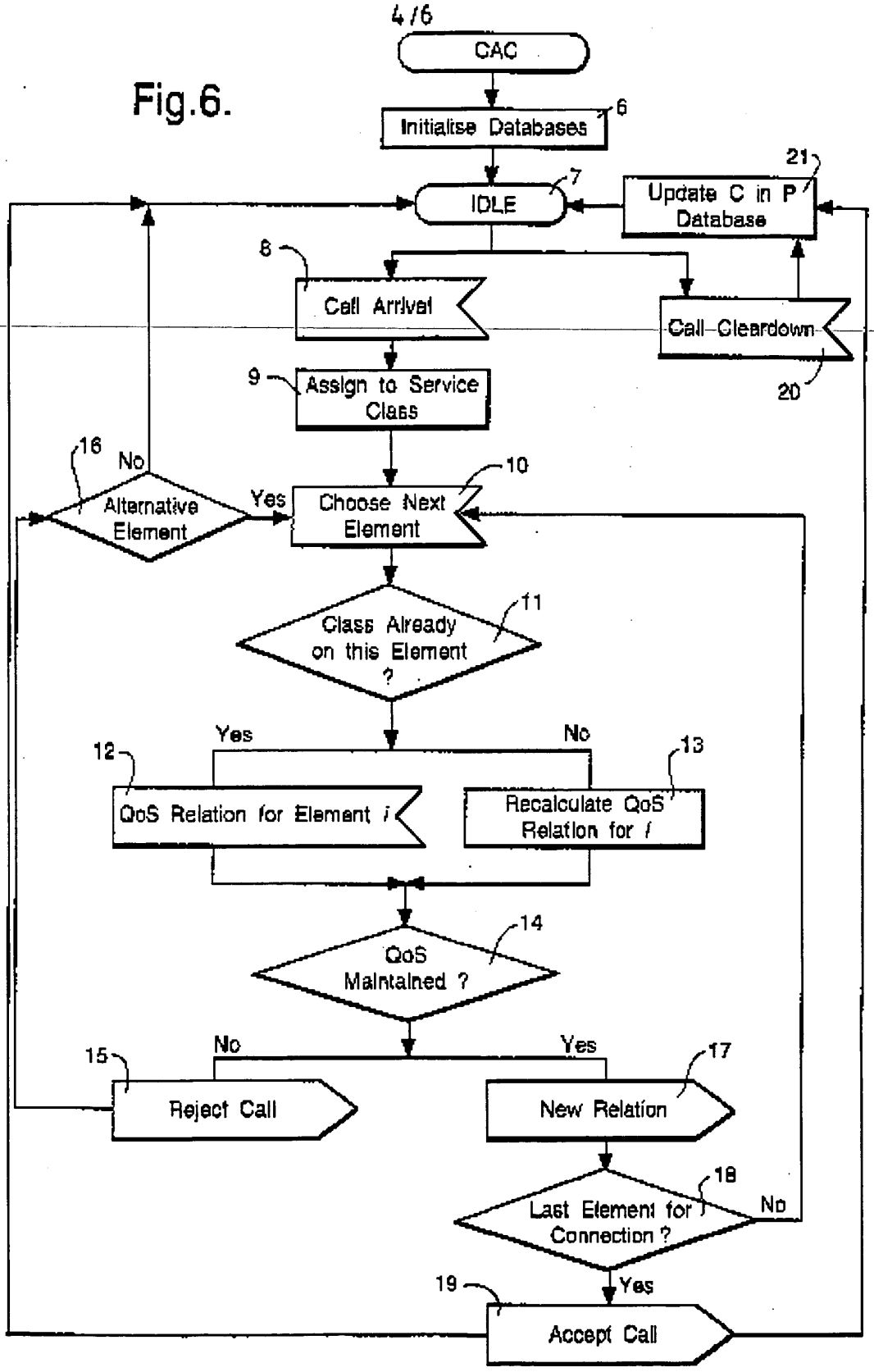

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Fig.7.

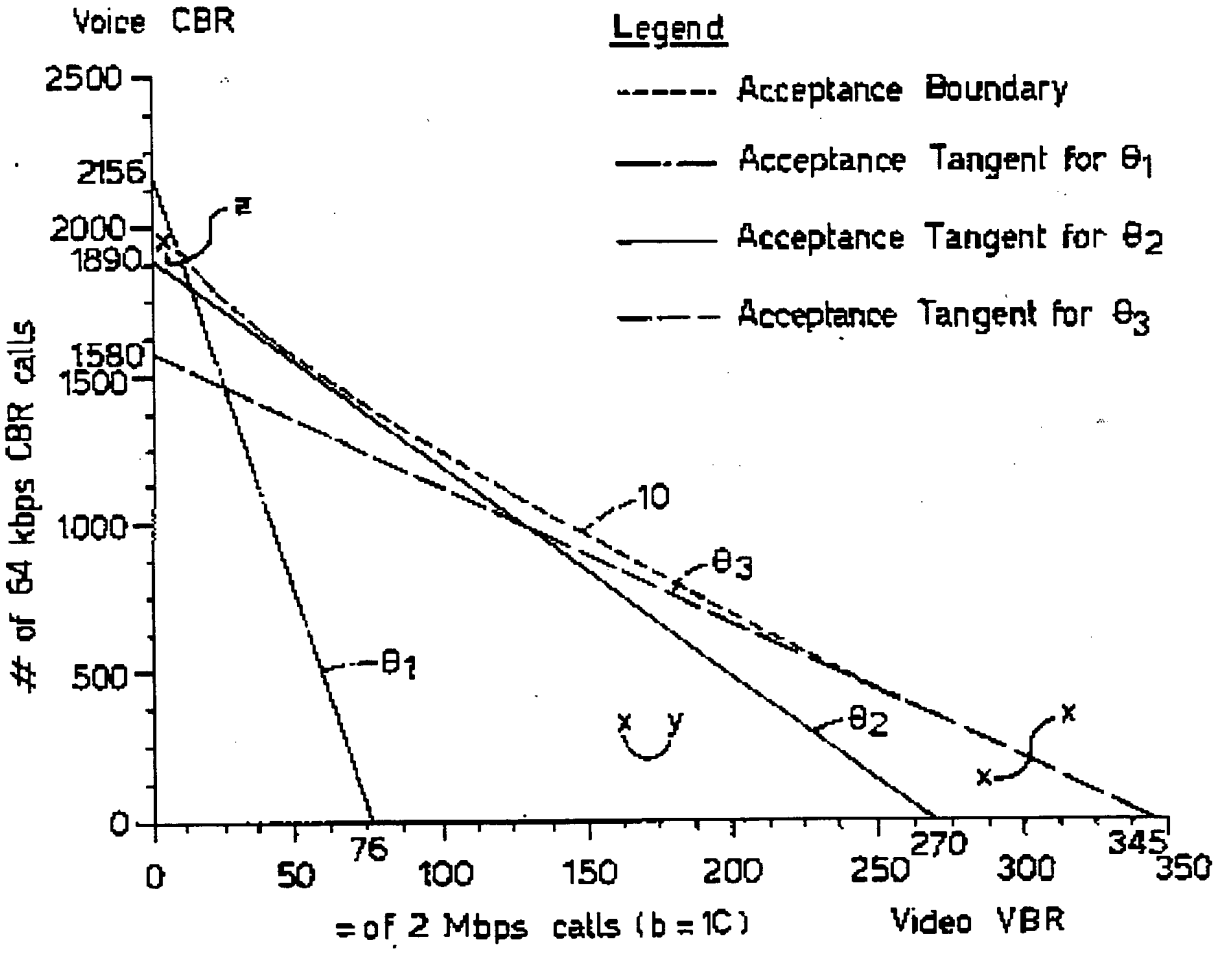

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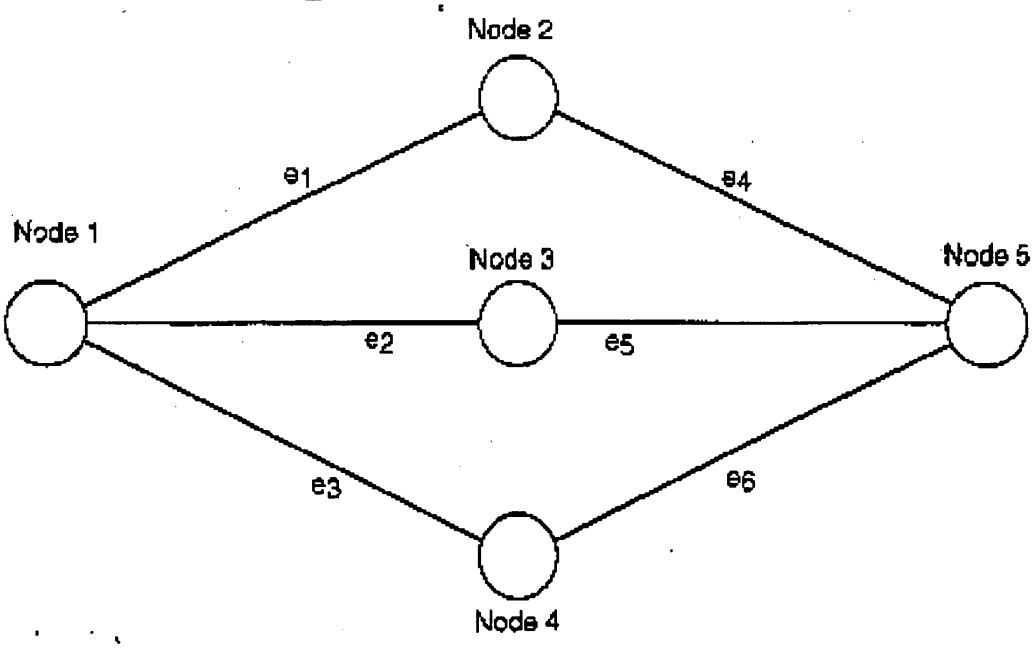
Fig.8.

Region	Threshold Regions for 64 kbps Calls	Threshold Regions for 2 Mbps Calls	Value for θ
θ_1	[1890,2156]	[0,345]	12.23
θ_2	[0,1890]	[0,270]	0.8333
θ_3	[0,1890]	[271,345]	0.4143

Fig.9.



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